Research Translation in Spatiotemporal Exposure Assessment for Contaminated River Superfund Sites

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Background

States are mandated by the federal Clean Water Act to provide an assessment of water quality along all streams and rivers. These assessments are used to identify river segments not attaining water quality standards and to establish pollutant budgets (TMDLs) that will bring these waters into compliance. However due to budget limitations the sampling data is generally insufficient to assess all river streams and a large fraction of river miles have not been adequately assessed. Therefore there is a need to develop <u>a method that can use the partial monitoring information available to estimate water</u> quality along the unmonitored network of streams and rivers.

Bayesian Maximum Entropy (BME) Method

The BME method is a powerful framework for incorporating the composite sapce/time variability of monitoring data into the mapping estimation of surface water quality. The BME method estimates water quality based on a space/time random field (S/TRF). There are 3 primary components to the BME method:

General Knowledge Base ($\mathcal{G}$): $\mathcal{G}$ consists of calculated means and modeled covariance based on the data available.

Site-Specific Knowledge Base ($\mathcal{S}$): $\mathcal{S}$ consists of hard data values obtained from EPA and USGS water quality monitoring stations in New Jersey

Posterior PDF: $\mathcal{G}$ and $\mathcal{S}$ are combined to create a probability density function (PDF) describing the water quality at any un-monitored estimation point in the space/time domain.

PCE Non-Attainment Assessment in New Jersey

Tetrachloroethylene (PCE) is one of the most frequently detected Volatile Organic Compounds (VOCs) in water systems across the U.S. In New Jersey, PCE concentration exceeded the state's water quality standard (0.388 μg/L) at several monitoring stations. By applying the BME method, we conducted the non-attainment assessment to verify how the PCE contamination vary over space and time.

1. Assessment Criterion

The space/time BME analysis generates a posterior probability density function (PDF) at each estimation point (Fig. 1-(a)). As shown in Fig.1-(b) the probability that the concentration exceeds the quality standard is obtained by calculating the area under the curve from quality standard value to Infinity. Using this method, we set a criterion that consists of the following three categories:

Highly Likely in Attainment	Prob[Non-Attainment]<10
Non-Assessment	10%≦Prob[Non-Attainment]≦90%
Highly Likely in Non-Attainment	Prob[Non-Attainment]>90%

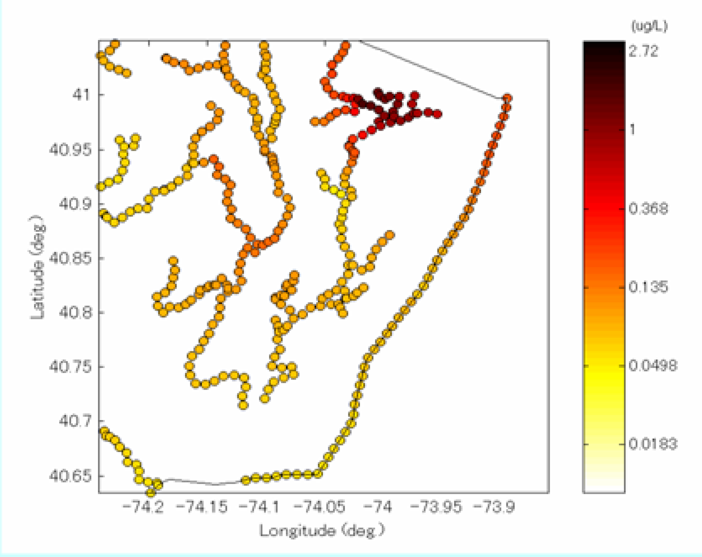

Fig.1-(a)

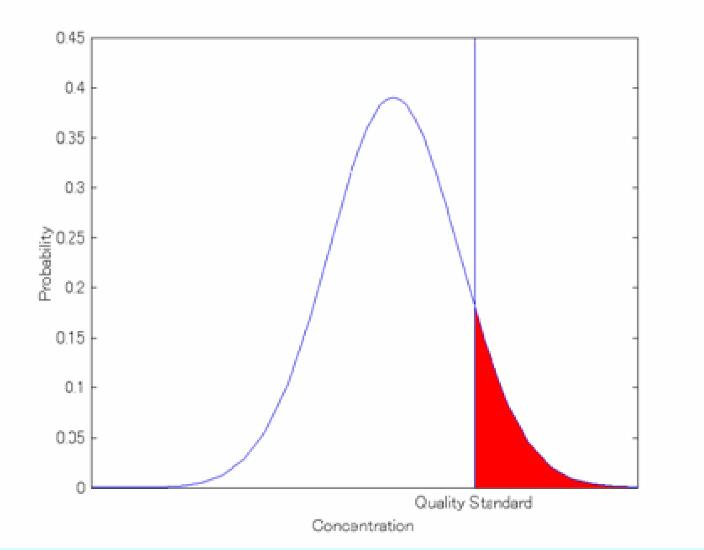

Fig.1-(b)

2. Identifying Contaminated Streams

New Jersey is divided into 20 watershed management areas (WMAs) (Fig.2-(a)). The contribution of each WMA to the fraction of river miles assessed as highly likely in non-attainment is shown in Fig.2-(b). This figure is useful to follow the evolution of non-attainment river miles. At the beginning of this period, only river streams in WMA5 and 10 did not attain the quality standard. Then, the fraction of river miles in non-attainment in these two areas gradually decreases, and instead shifted to other WMAs.

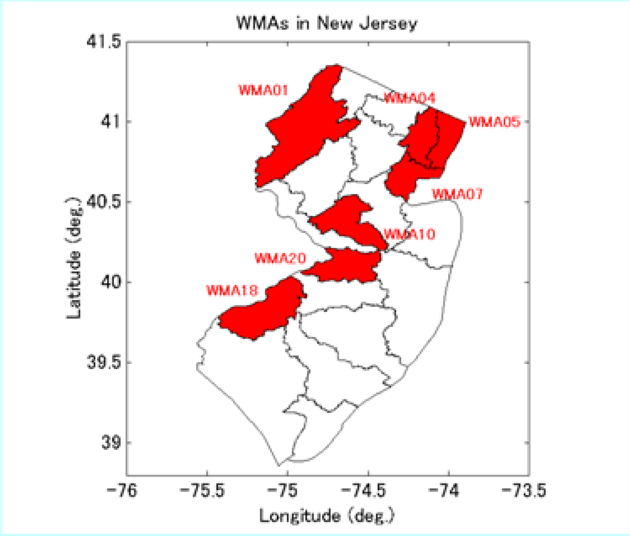

Fig.2-(a)

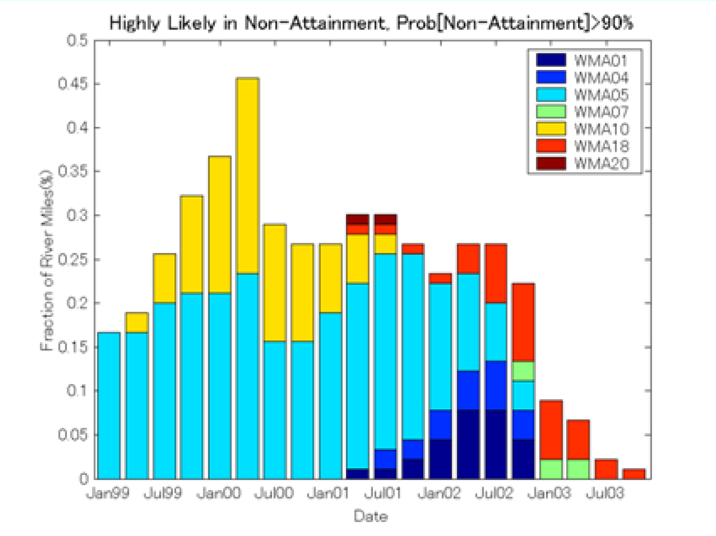

Fig.2-(b)

3. Space/Time Approach vs. Conventional Approach

Using a cross validation analysis, we found that the Mean Square Error (MSE) for the space/time analysis was 56% smaller than that of the spatial analysis, indicating that our space/time analysis results in a substantial gain in mapping accuracy. Furthermore In Fig.3, we show the time series of the fraction of river miles calculated using (a) the composite space/time analysis and (b) a purely spatial analysis. In the purely spatial analysis, the fraction of non-assessed river miles reached about 99% in 2002. On the other hand, this fraction never exceeds 25% for the space/time analysis.

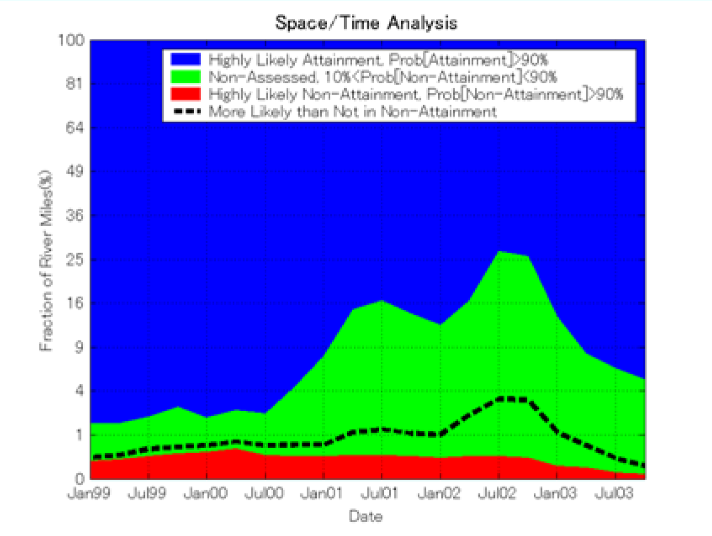

Fig.3-(a)

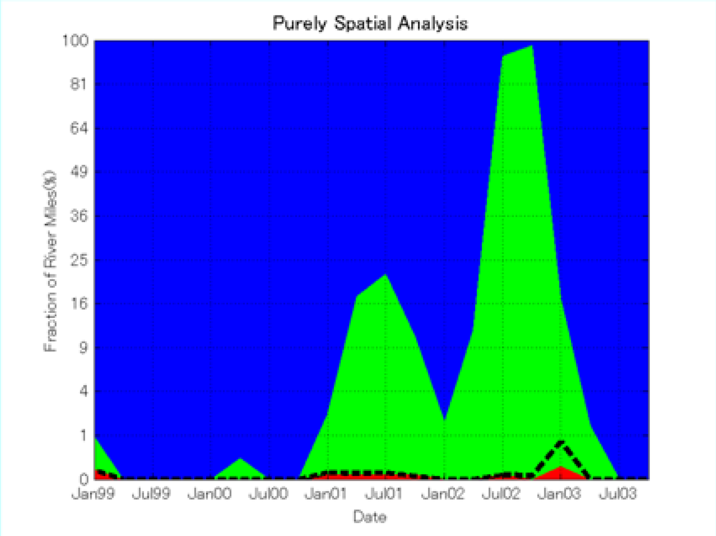

Fig.3-(b)

Space/Time GUI Tool

Even though the framework presented here is powerful, no easy-to-use tool is available. In order to address this issue, now we are developing the graphical user interface (GUI) tool (Fig.4) which allows stake holders to perform the space/time analysis and makes them free from the tedious programming work.

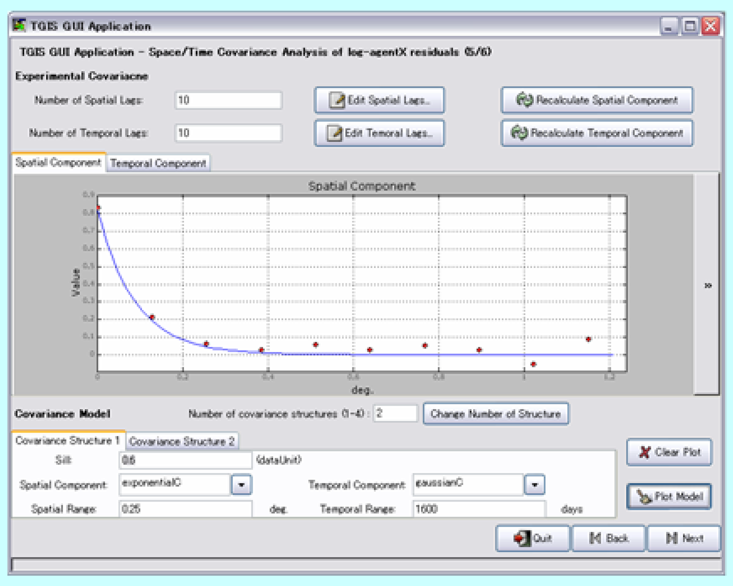

Fig.4-(a)

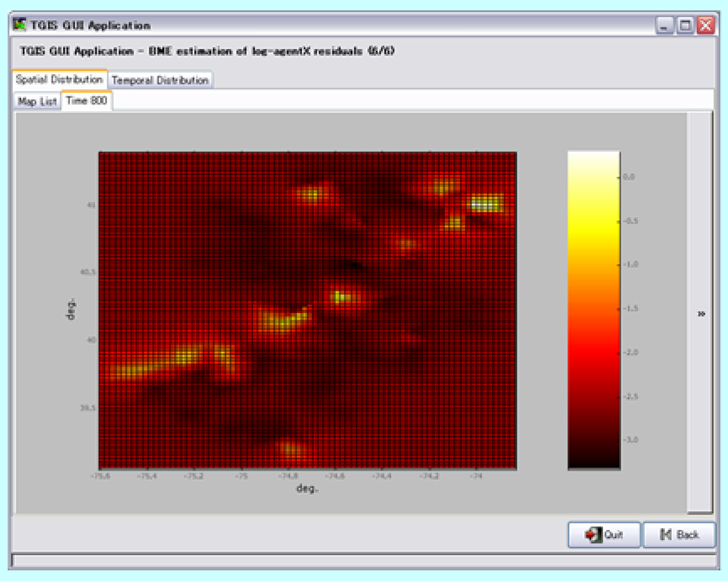

Fig.4-(b)

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